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ABSTRACT

Universities are often accused of being "ivory towers" that are divorced from the "real worlds" of industry and commerce. Similarly, it is argued that academics teach "yesterday's science," and that they are unaware of modern developments in technology and engineering. When it is realized that the research budgets of some large organizations exceed the total yearly expenditure that many nations spend on their universities, the question needs to be asked, how can universities ensure that their research programs are relevant to modern industry and that lectures are up-to-date? The answer is to collaborate with industry to the advantage of all parties concerned. Collaboration helps universities, industry, and the student and supervisor involved. For example, UMIST is completely committed to collaboration with industry at all levels, from undergraduate projects to doctoral research. For the past 20 years, UMIST has operated a Total Technology (TT) program across all engineering and applied science disciplines with UK industry. For the past 6 years, UMIST has also operated, in collaboration with the University of Manchester, an Engineering Doctorate program, again in association with industry. The Manchester TT and engineering doctorate (EngD) programs now have over 120 doctoral students working in collaboration with all sizes of UK firms. This represents the largest collaborative doctoral program in the UK. The lessons that have been learned and how they might be successfully applied are described. (Author/YDS)

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POSTGRADUATE TRAINING & RESEARCH IN COLLABORATION WITH INDUSTRY (TWENTY YEARS OF EXPERIENCE IN THE U.K.)

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ABSTRACT

Universities are often accused of being 'Ivory Towers' that are divorced from the 'real worlds' of industry and commerce. Similarly, it is argued that academics teach 'yesterdays science', and that they are unaware of modern developments in technology and engineering. When it is realised that the research budgets of some large organisations exceeds the total yearly expenditure that many nations spend on their universities, the question needs to be asked 'how can universities ensure that their research programmes are relevant to modern industry, and that lectures are up-to-date. The answer is to collaborate with industry to the advantage of all the parties concerned. Collaboration helps Universities, Industry, and both the student and supervisor involved.

For example, UMIST is completely committed to collaboration with industry, at all levels, from undergraduate projects to doctoral research. For the past 20 years, UMIST has operated a Total Technology programme, across all engineering and applied science disciplines, with UK industry. For the past 6 years, we have also operated, in collaboration with the University of Manchester, an Engineering Doctorate programme, again in association with industry.

The Manchester TT and EngD programmes now have over 120 doctoral students working in collaboration with all sizes of UK firms. The growth of the Departments activity is shown in (Table 1). This represents the largest collaborative doctoral programme in the UK. The lessons which have been learned, and how these might be successfully applied, are described within the paper.

R. Leonard

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Table 1

Growth of TT/EngD Doctorate at Manchester

	1977	1981	1985	1989	1993	1997
Total Tech	4	8	16	32	60	67
EngD					25	56

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INTRODUCTION

During recent decades the traditional approach to doctoral research in the U.K. has been criticised regarding its ability to produce engineers and scientists who are suited to the management needs of companies. It has been implied that a PhD, conducted within a University laboratory in a narrow field of study, is too specialised to meet the demands of modern industry. Thus a range of approaches to postgraduate industrial education have been established in the UK, two of these are the Total Technology PhD programme, and the recently established Engineering Doctorate (EngD).

These schemes have operated successfully for a considerable time, TT for 20 years, and EngD for the last 6 years in Manchester. Currently there are over 120 doctoral students on these two programmes, collaborating with all sizes of UK companies. The Engineering Doctorate was jointly developed by government, Industry and Academia to meet the needs of industry in the next century. It should be noted that industrial collaboration is one of the main factors towards producing the next generation of world-class industrial managers, and it can also serve as a useful means of protecting the natural environment. It must be noted however, that without the use of government funding to act as a catalyst for bringing together industry and academia, it is unlikely that industry/university collaborative research will ever gain any impetus.

TOTAL TECHNOLOGY

The objective of Total Technology is to provide outstanding applied scientists and engineers with a broadly based training such that they can hold senior positions within industry at an early stage of their careers. Total Technology brings together the best aspects of a conventional PhD, and combines them with the realism of linking the research with an industrial enterprise. Engineering comprises people, planning, research, development, design, production, finance, marketing and the operation of plant. In a real project these areas merge into one another and each has an interrelationship with the others. Success in industry can only be achieved by obtaining solutions which are a well-balanced synthesis of all these functions. Total Technology is the name which Professor Sir Hugh Ford, the pioneer of Total Technology, gave to cover this wide spectrum of functions together with the management skills to weld them together. It is unlikely that a specific Total

Technology investigation would encompass all the activities which exist within a typical enterprise. More probably the project would involve an in-depth study relating to two or three categories, with the other functions being covered in less detail. For example, a project concerned with the computer assisted design of a high speed textile machine would consider any manufacturing problems associated with the parts designed, together with an awareness of the advantages from such a machine in terms of marketing considerations. Similarly, a project dealing with the selection of advanced, numerically controlled machine tools would need to encompass the following areas: component analysis, machine specification, the selection of cutting conditions, manning levels, factory layout considerations, design standards, finance, reliability and maintenance.

Because of its application to a range of disciplines, the Total Technology concept must be interpreted to suit specific situations dependent upon the interests of collaborating companies and the researchers. Different interpretations can lead to a variety of solutions in terms of research methods, education and training, but in every case the student must spend 25% of his/her time working in the sponsoring company assessing the commercial impact of the research. In addition, the student is supported by suitable lecture courses within the university, industrial seminars, discussion groups and by contact with fellow researchers. Thus, at the end of a Total Technology programme, successful students gain the degree of PhD together with valuable industrial experience within a company. This assists them in filling senior industrial appointments at an early stage of their careers.

THE PROGRAMME

The Total Technology programme has a high degree of flexibility of operation. Thus the specific needs of individual students are catered for within the scheme, whilst retaining the overall objectives of Total Technology. The programme is equally suited to new graduates or those with postgraduate experience. Each student has an academic supervisor who is responsible for the project and the well being of the student. The student is registered for the degree of PhD within the department of the supervisor, and a thesis is submitted and examined in the traditional manner.

Total Technology is a joint venture between government, industry and academia. The programme spans all Engineering and Applied Science departments in UMIST and the University of Manchester. The breadth of the Manchester programme has allowed it to progressively expand to the point where sixty seven PhD projects are being pursued in a very wide spectrum of UK companies.

The four pre-requisites for success relating to Industrial/University co-operation are:

1) An able, well-motivated student
2) A well selected project
3) An enthusiastic academic supervisor
4) A company which is keenly interested in the projects success.

The projects available primarily result from the well established contacts, built up over many years, between university staff and specific companies. Each year over 50 Total Technology project proposals are received from members of staff, and their industrial partners. Thus three of the four pre-requisites have been fulfilled before the project is defined as Total Technology and

presented to the potential student.

THE ENGINEERING DOCTORATE

Despite the apparent success of Total Technology in Manchester this was not replicated at other Universities. In 1990 the Science and Engineering Research Council set up a working party to study postgraduate research training in Britain, and to establish its effectiveness in satisfying the needs of industry compared to schemes operated in other major industrial nations. The result of the report was the instigation of the new EngD degree. This takes highly qualified and well motivated young engineers, and puts them through FOUR YEARS of training, involving industry based research and taught management courses. (Engineers already possessing an MSc can complete the course in THREE YEARS). This is a significant deviation from all previous doctoral programmes in Britain, as both the research and taught elements must be passed in order to gain the EngD degree.

It is considered that the well-funded Government/Industry EngD approach to research combines the best aspects of a conventional PhD with the practical implications of linking the research to the specific needs of a collaborating company. This is supported by formal lecture courses and a personal and professional development programme. Therefore, at the end of the programme, successful Research Engineers have not only gained the EngD degree but they have also received valuable industrial experience and in-company training. Holders of the EngD are therefore on a "fast track" to promotion into senior management positions at an early stage in their career. The starting salaries for EngD graduates are high. For engineers not wishing to take this integrated, 4 year approach, the traditional Total Technology PhD still provides the main source of industrial research training at Manchester.

THE PROGRAMME

The Manchester EngD programme has been designed for students who wish to pursue a career in industrial management. Each Research Engineer undertakes an intellectually challenging research investigation with industry, including approximately 50%, working with professional engineers and managers. This is supplemented by examined management and technical lecture courses, together with seminars and workshops to enhance personal and professional development.

Each project has an academic supervisor and an industrial collaborator. Principle objectives are that Research Engineers become competent to analyze industrial problems, take decisions within the limits of the information available and communicate these decisions effectively. The framework for an EngD study include:

* a challenging industrial problem of high technical merit
* assessing the relationship of the work to corporate strategy
* studying influences from the marketplace and environment
* project management within the defined timescale and budget
* economic and financial considerations
* leadership and teamwork
* defining design and production requirements

Each Research Engineer is counselled regarding effective collaboration, a viable research methodology and the overall needs of the doctoral thesis. It is important that the industrial objectives of the research programme should be met, and that the doctoral thesis treats the company as a case study within which a general approach can be developed/tested. It is necessary for the Research Engineer to become fully integrated within the companies research team, and this is the responsibility of the industrial advisor. Research Engineers often have budget control and are responsible for part of the project management activity.

The final part of the EngD course is a Supporting Studies programme. This produces a sense of common purpose amongst Research Engineers working in a wide range of companies and university departments. A significant amount of this is on residential weekend courses. Research Engineers are exposed to team activities via sophisticated Business Games and small group projects. Design and Project Management seminars bridge the engineering disciplines on the programme. Personal skills are developed via courses on effective report writing and making presentations. These skills will be applied in the company during the course of the project. All Research Engineers keep a log book to record their professional development in preparation for attaining full Chartered Engineer Status. An experienced engineer is employed solely to support the Research Engineers in planning their professional development and using all the resources of the university and the company to their best effect.

It can be seen from the above that the EngD degree at Manchester is not for the faint hearted. However, for those taking on the challenge, it becomes one of the most rewarding periods of their careers, leading into a well-paid position in industry.

TYPICAL FOUR YEAR TIMETABLE FOR RESEARCH ENGINEERS

The programme for EngD studies is described below:

Year 1:
Upon starting the programme, Research Engineers attend an introductory weekend to develop teamwork skills and self awareness. This is followed by a three month period of intensive study into the background of the research, the identification of technical lectures to support research, the development of a research strategy and the introduction to the sponsoring company (October through December). During the subsequent three months, in addition to progressing the research programme, attendance is required at the university for the first four modules of the Diploma in Management. The Diploma lectures are examined and must be passed before a Research Engineer can progress to Year 2. In the final three months, the Research Engineer produces a significant report on the first year's activities and sets out, in detail, plans for the subsequent three years.

Year 2:
Year 2 progresses in much the same way as Year 1, except that there is an in-company presentation of the progress of the project. Senior management of the company and university representatives attend the presentation. The final four modules of the Diploma in Management are taken during this year, and must be passed before the RE can progress to Year 3. Once again a report of the year's activities, setting out objectives for the next two years, is produced and

assessed.

Years 3 & 4:
Years 3 and 4 are given over almost entirely to industrial research activities. Attendance at a small number of special lectures is required, and visits to diverse industrial organisations are arranged. As with previous years, a progress report is required at the end of Year 3.

At the end of Year 4, a doctoral thesis is submitted for examination for the degree of EngD.

THE ENGINEERING DOCTORATE AT MANCHESTER

The Manchester EngD programme is coordinated through the Total Technology Department at UMIST, on behalf of UMIST and the University of Manchester.

The EngD degree is intended to take highly qualified and well motivated young engineers and put them through a four year training programme, involving :

- Industry based/linked research
- Taught management courses
- Seminars and workshops to promote professional development and interpersonal skills.

The EngD programme is designed with the following specific objectives:

a) To provide Research Engineers with a training in research that is equivalent to a PhD, but different in kind.

b) To develop, in the Research Engineer, the following competencies.

- Expert knowledge of an engineering subject
- The appreciation of industrial engineering and development culture
- Project management skills against realistic timescales
- Teamwork and leadership skills
- Communication skills - oral and written, technical and non-technical
- Technical organisational skills
- Financial project planning and control
- The ability to apply his or her skills and knowledge to new and unusual situations
- The ability to seek optimal, viable solutions to multi-faceted engineering problems, and to search out relevant information sources
- An evaluation of the environmental impact of industry, and how to minimise environmental problems.

In order to achieve these objectives, the EngD at Manchester was designed with three core elements :

- A major research project working on an industrial problem
- A Diploma in Management
- A Supporting Studies programme

For each of these elements to be integrated effectively, a training partnership is required involving the universities, a specific company and the individual Research Engineer.
Each partner has a specific role to play and, in return, should receive specific benefits.

LESSONS WITH REGARD TO DOCTORAL COLLABORATION

Collaboration between industry and academia provide many benefits for all the parties concerned. The doctoral student gains valuable 'hands on' experience of industry at all levels, from shop floor to boardroom, and this greatly enhances career opportunities with regard to senior positions within industry. The student also receives a financial supplement from the firm, as well as the Government grant, and has the advantage of advice from two supervisors, academic and industrial. The company have the advantage of an additional well qualified researcher, access to University staff and equipment, and a literature survey spanning the world. The University ensures that research is industrially relevant and timely, and yet they may avoid the cost of purchasing state of the art equipment, within their own laboratories, by making use of the collaborating firms resources. The country gains the advantage of ensuring that doctoral research is relevant to the real needs of industry, and that the universities are generating doctoral graduates who can quickly fill senior industrial positions within their country.

For a country such as the United Kingdom, the wide diversity of industry means that the Total Technology and Engineering Doctorate programmes are widely dispersed. For some countries however, it could be advantageous to concentrate such programmes on key industrial sectors, such that specialist but highly relevant centres of excellence would be created within key universities. These areas could include petrochemicals, environmental controls, and similar prime activities. It is therefore advocated that the governments make significant funding available with regard to key areas of activity, and that the universities, in association with industrial partners, should bid to be a centre for a specific activity. The government funding would cover the operating costs of each centre and fund the grants of up to 30 doctoral students at each of these centres. Industry would be expected to be intimately involved with these centres, both financially and operationally. From this base, programmes can be established within the general doctoral requirement that a specific piece of research is highly relevant to the needs of the firm whilst, at the same time, being academically worthy of a doctorate being awarded. If these 'Centres of Excellence' were closely associated with 'World Centres of Excellence' and Business Schools in the corresponding disciplines, then world-class Industrial Managers could jointly be trained by all the associated parties. It cannot be too strongly emphasised that for collaborative work with industry to succeed then a partnerships must be established between Government, industry and a university. Government provides funds and acts as the pro active catalyst between academia and industry. Academia establish industrially relevant courses and actively seek to work effectively with industry on the solution of real problems. Industry recognise that for collaboration to be successful it must not only deal with short term problems but it must also deal with long term research studies of significant intellectual challenge. When all three partners accept the reality of their responsibilities then the result is highly beneficial to everyone concerned, especially the next generation of industrial managers in an highly technological age.

CONCLUSIONS

In the modern world the pace of technological advance is ever more rapid.

Thus, for lectures and research to be relevant, universities need to collaborate at all levels with industry. This paper has shown that collaboration at doctoral level is highly beneficial for all the parties concerned, and that both Total Technology and the Engineering Doctorate offer realistic and cost effective ways forward.

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